Radiation Monitoring During Decommissioning at Indian Point

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October 3, 2021

Definition of Radioactive Materials

RADIOACTIVE MATERIALS contain unstable atoms that seek stability by emitting radioactivity in the form of neutrons, alpha particles, beta particles, and gamma rays.

Sources of Radioactive Materials

The primary sources of radioactive materials at a nuclear power plant are:

- **FISSION PRODUCTS**
- **ACTIVATION PRODUCTS.**

Sources of Radioactive Materials

FISSION PRODUCTS

Atoms fission, or split, into two smaller atoms, and not always the same two smaller atoms.

Many of these fission product atoms are unstable and seek stability by emitting radiation in the form of particles or energy waves.

Sources of Radioactive Materials

ACTIVATION PRODUCTS

Non-radioactive material can become activated by interactions with radiation (e.g., get hit by neutrons or gamma rays).

CHEMICAL INJECTION – many plants inject chemicals that "coat" pipes to retard rusting and corrosion; some of these chemicals get activated

RADIOLYTIC DISASSOCIATION – water molecules flowing through the reactor core can get broken apart into hydrogen and oxygen molecules; subsequent interactions involving oxygen and nitrogen molecules can form Carbon-14

RUST AND OTHER PARTICLES – debris in the water can get activated flowing through the reactor core

Sources of Radioactive Materials

ACTIVATION PRODUCTS

Example: Boron is dissolved into the water circulating through the reactor core to help control the nuclear chain reaction.

A boron atom absorbing a neutron can produce helium and tritium byproducts.

Tritium, a radioactive isotope of a hydrogen atom, can combine with oxygen to form tritiated water (or tritated water vapor).

Forms of Radioactive Materials

LIQUID

Fission products leaked into water or activation products created in water or carried by water form radioactive liquids.

GASEOUS

Radionuclides "bubble" out of water or evaporate to form radioactive gases.

SOLID

Filter/demineralizers that purify water, water soaking into concrete, pipes activated by irradiation are radioactive solids.

Radioactive Materials Then and Now

During reactor operation, there were lots of fissions, lots of water circulating, and lots of systems handling contaminated water.

During decommissioning, there are fewer fissions, less water circulating, and fewer systems handling contaminated water.

What difference does it all make?

NUREG-0586, Supplement 1
Volume 1

Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities

Supplement 1

Regarding the Decommissioning of Nuclear Power Reactors

Main Report, Appendices A through M

Final Report

Manuscript Completed: October 2002
Date Published: November 2002

This report contains data on radioactive material releases and radiation doses during operation and decommissioning.

Source: https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML023470304

Radioactive Materials Then and Now

	Operating PWRs Average (Curies)	Decommissioning PWRs Average (Curies)	Decommissioning/Operating Percent
Total Gaseous Effluents	58.00	21.00	36.2%
Fission and Activation Gases	44.00	16.00	36.4%
Iodines	0.00	0.00	0.0%
Particulates	0.00	0.00	0.0%
Tritium	14.00	13.00	92.9%
Total Liquid Effuents	520.00	0.78	0.2%
Fission and Activation Gases	0.16	0.04	21.9%
Tritium	520.00	0.74	0.1%
Dissolved and Entrained Gases	0.10	0.00	0.0%
Gross Alpha	0.00	0.00	0.0%
Total Gaesous and Liquid Effluents	578.00	21.78	3.8%
Tritium	534.00	13.74	2.6%

The data from Table G-15 shows that the releases of liquid and gaseous radioactive materials, with the exception of airborne tritium, are significantly less at a decommissioning plant than at an operating plant.

Radioactive Materials Summary

Although the amounts of radioactive materials created, stored, and released during decommissioning are less than the amounts during reactor operation, the federal regulations governing monitoring, control and reporting of radioactive materials remain the same because workers and the public still require protection.

Continuous vs Sampling Monitoring

Some radiation detectors monitor continuously for gamma rays, beta and alpha particles.

Some radiation detectors blow air through filters that collect particles. The filters are collected weekly or monthly and sent to labs for analysis.

Figure 3-2
GammaCam System.

Tools like this GammaCam allow workers to "see" radioactively contaminated materials.

Figure 3-4
Maine Yankee Overhead Source

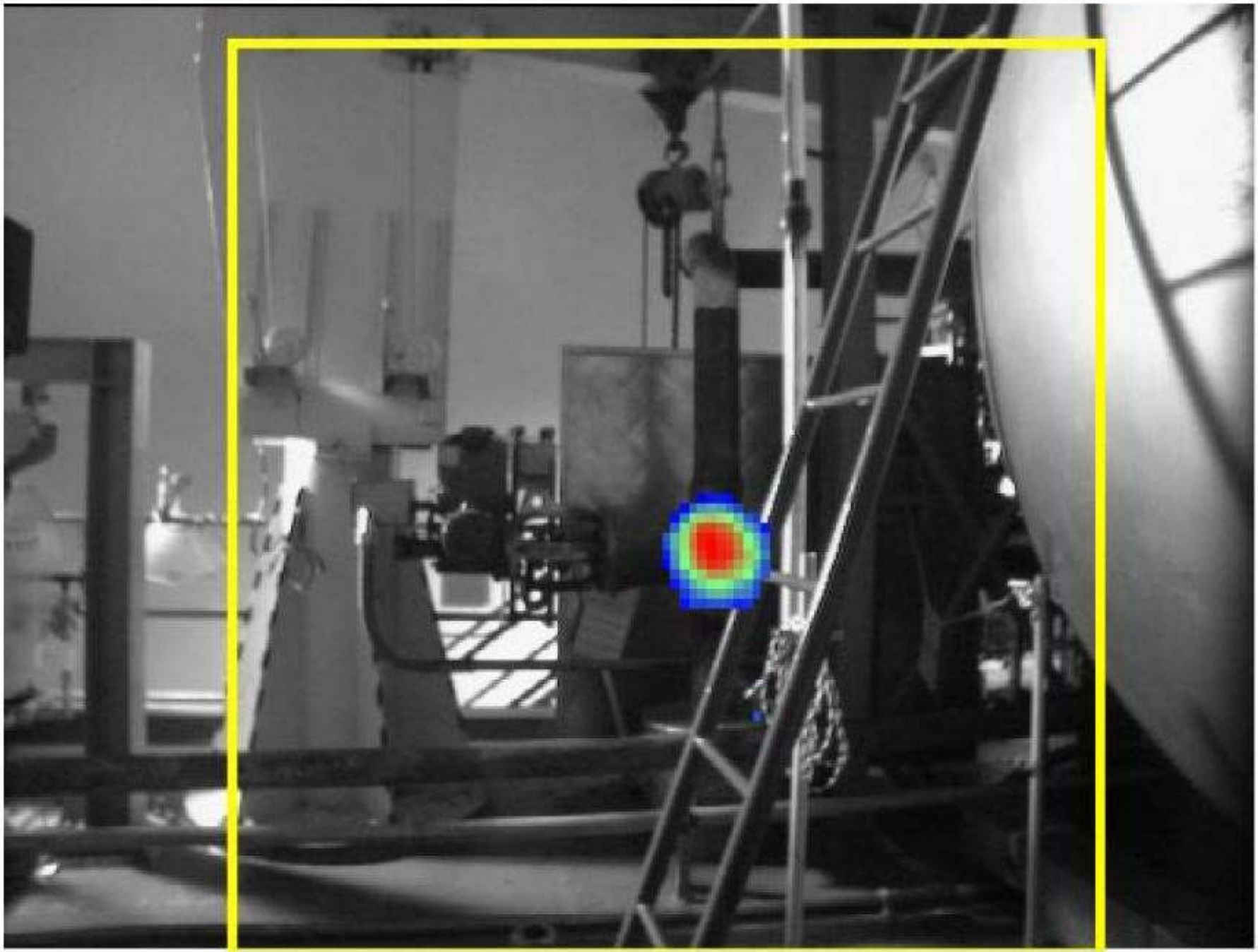
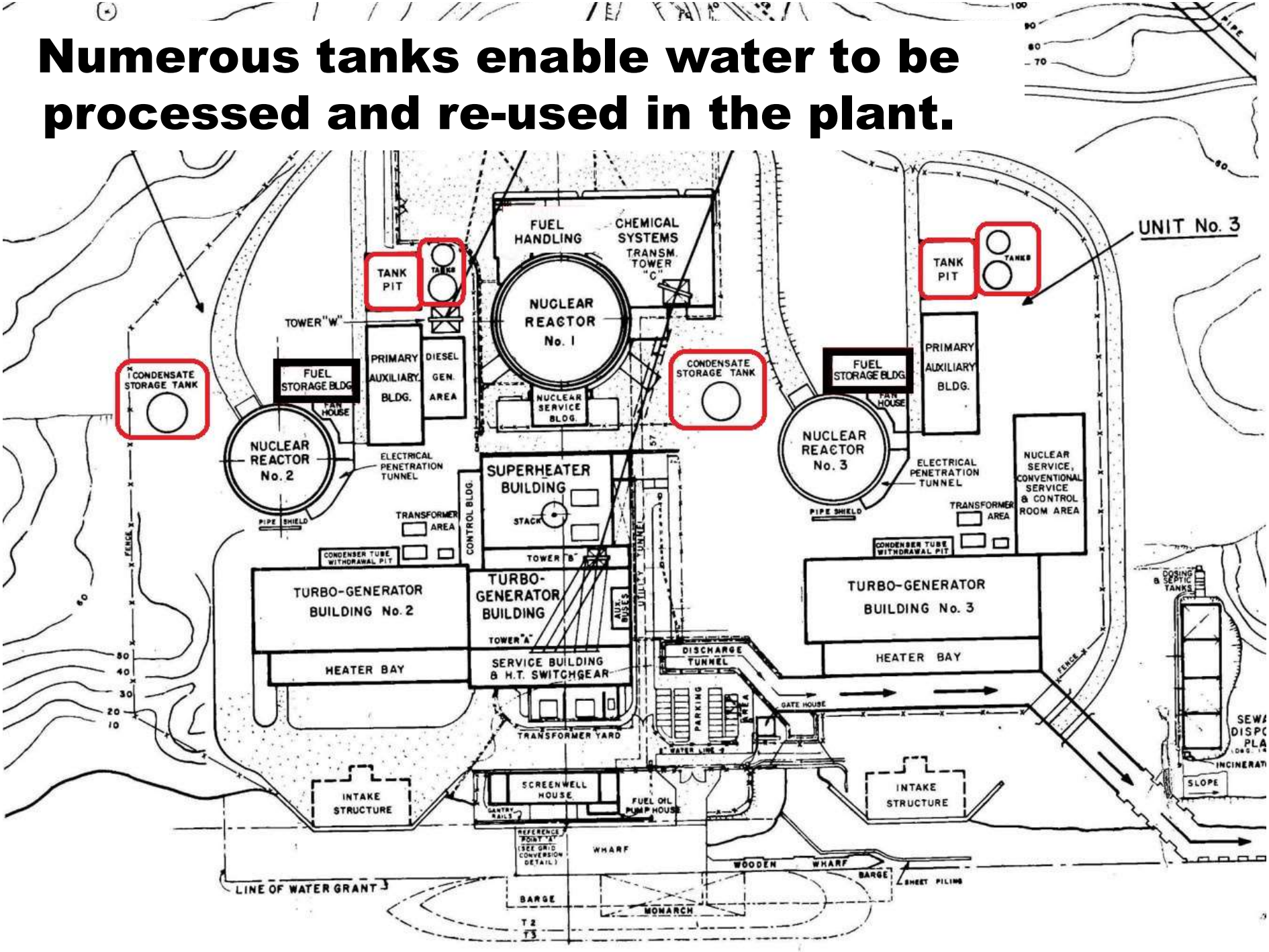


Figure 3-13
Big Rock Point Emergency Cooling System Area

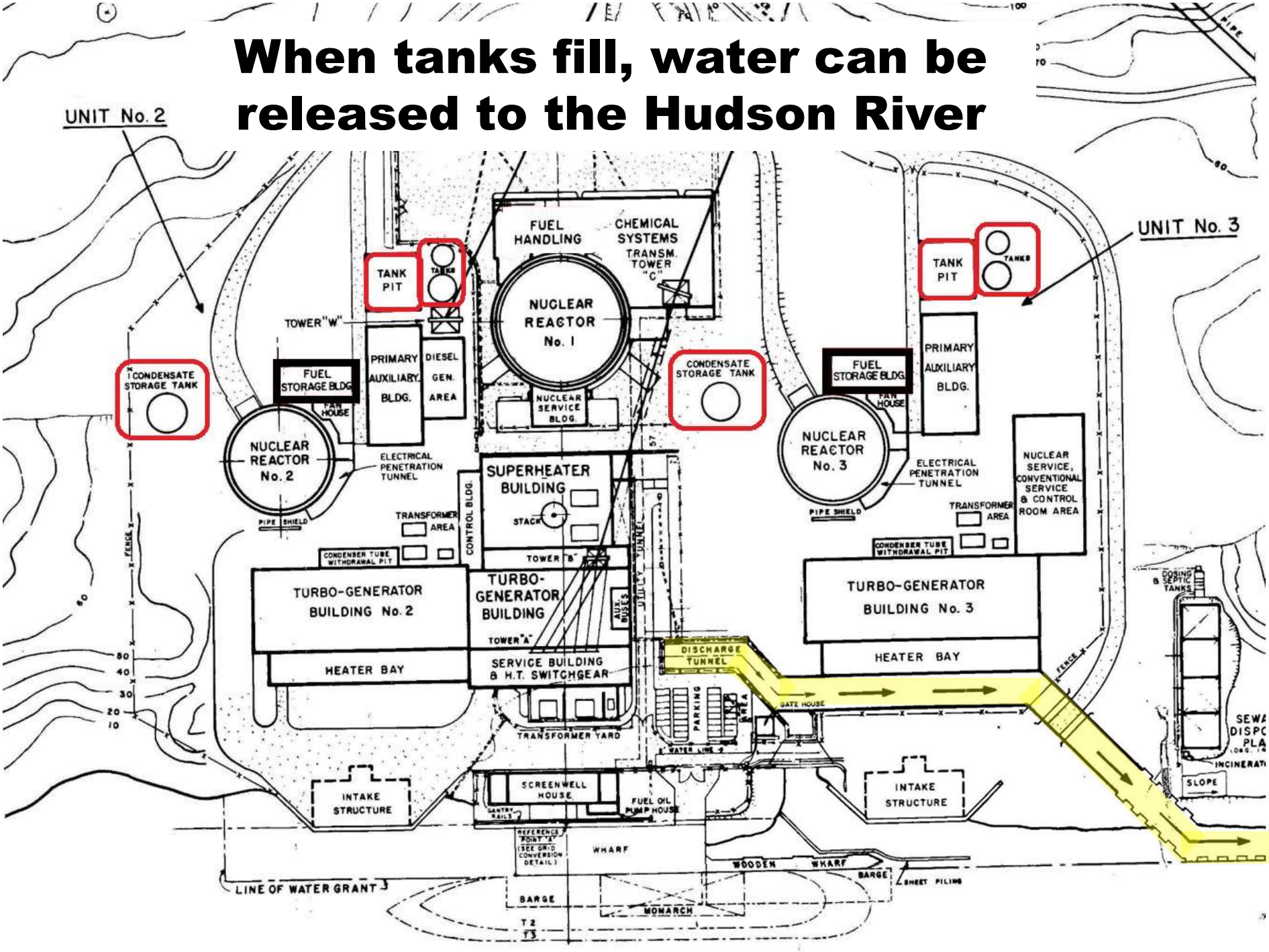
Control of Radioactive Liquids

Numerous tanks enable water to be processed and re-used in the plant.

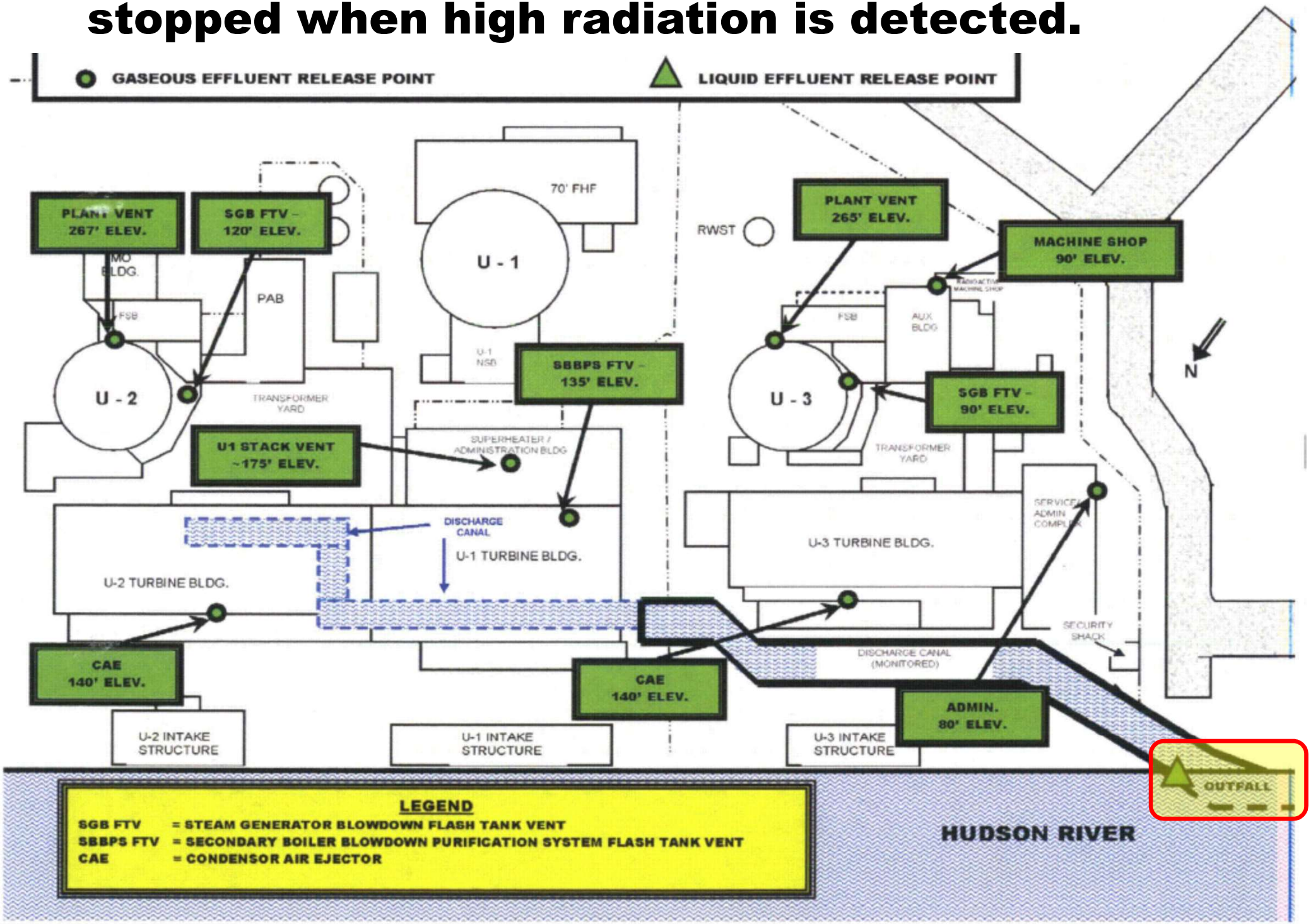


Control of Radioactive Liquids

When tanks fill, water can be released to the Hudson River



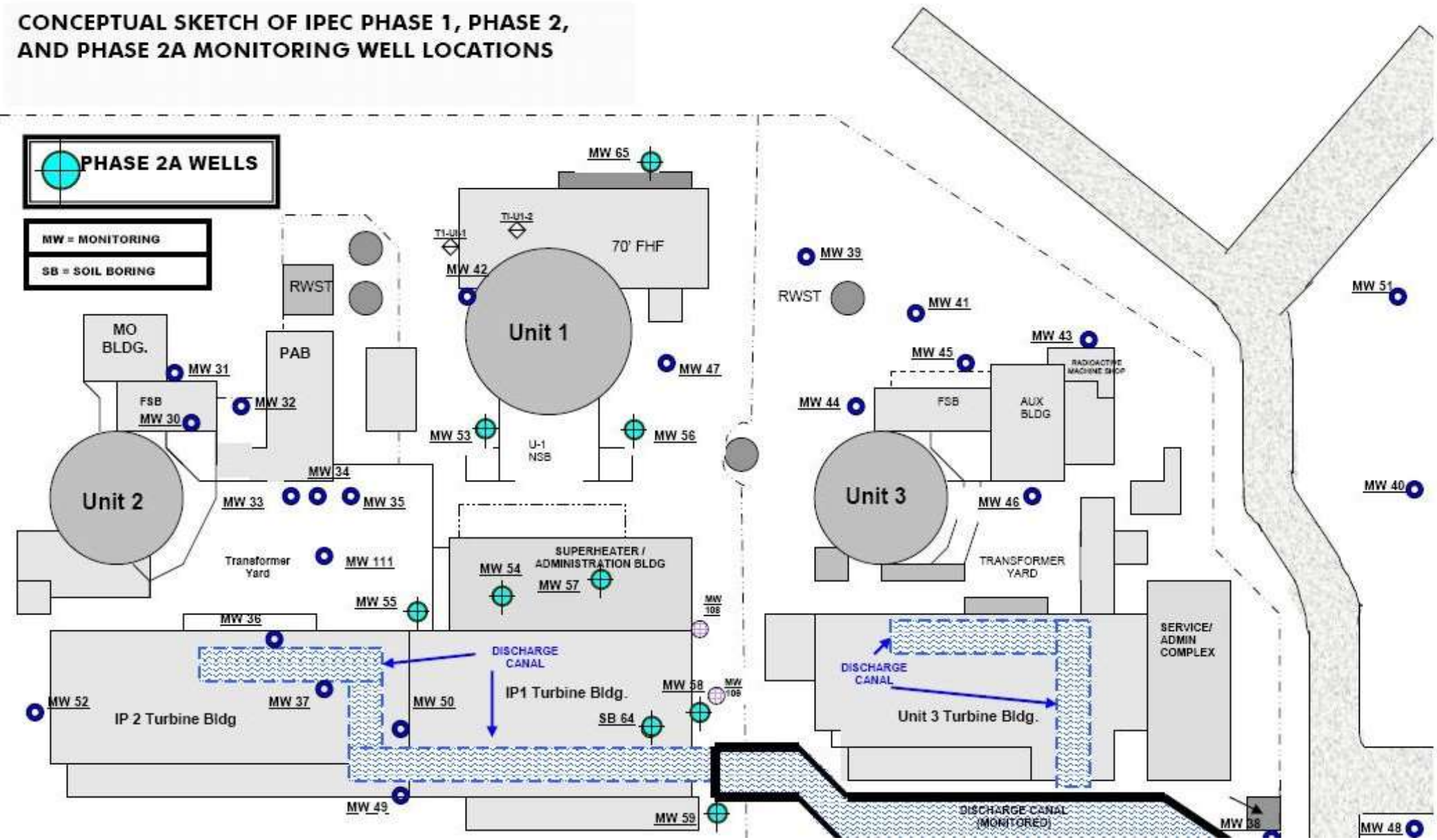
That pathway is monitored and the release is stopped when high radiation is detected.



Radioactive Material Accounting

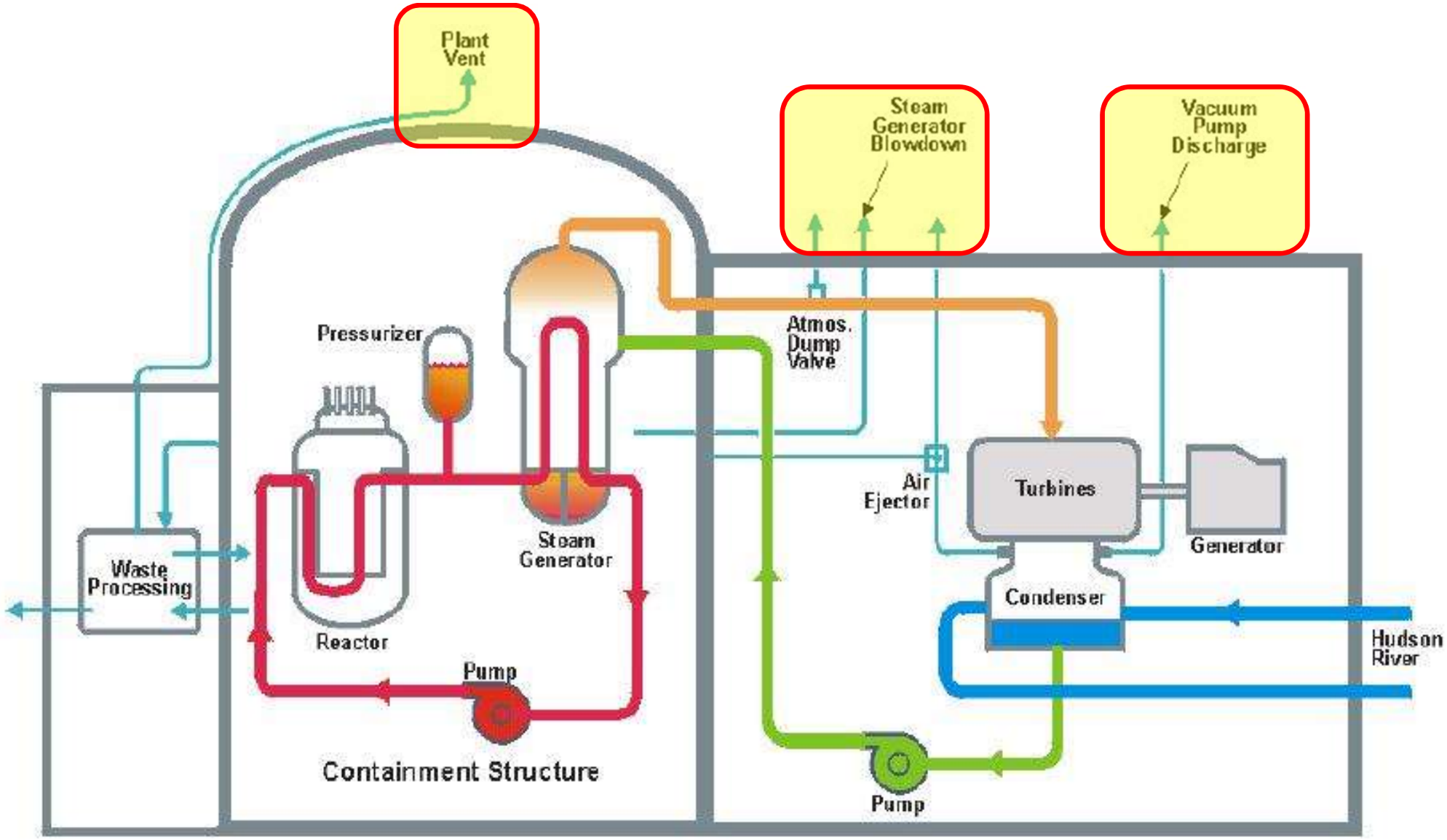
Before a tank of radioactively contaminated water is discharged to the river, a sample is taken and analyzed to determine the concentrations of its radionuclides. The amount of water discharged is recorded. The concentrations multiplied by the volume of water released determines the total quantity of each radionuclide released.

Control of Leaked Radioactive Liquids



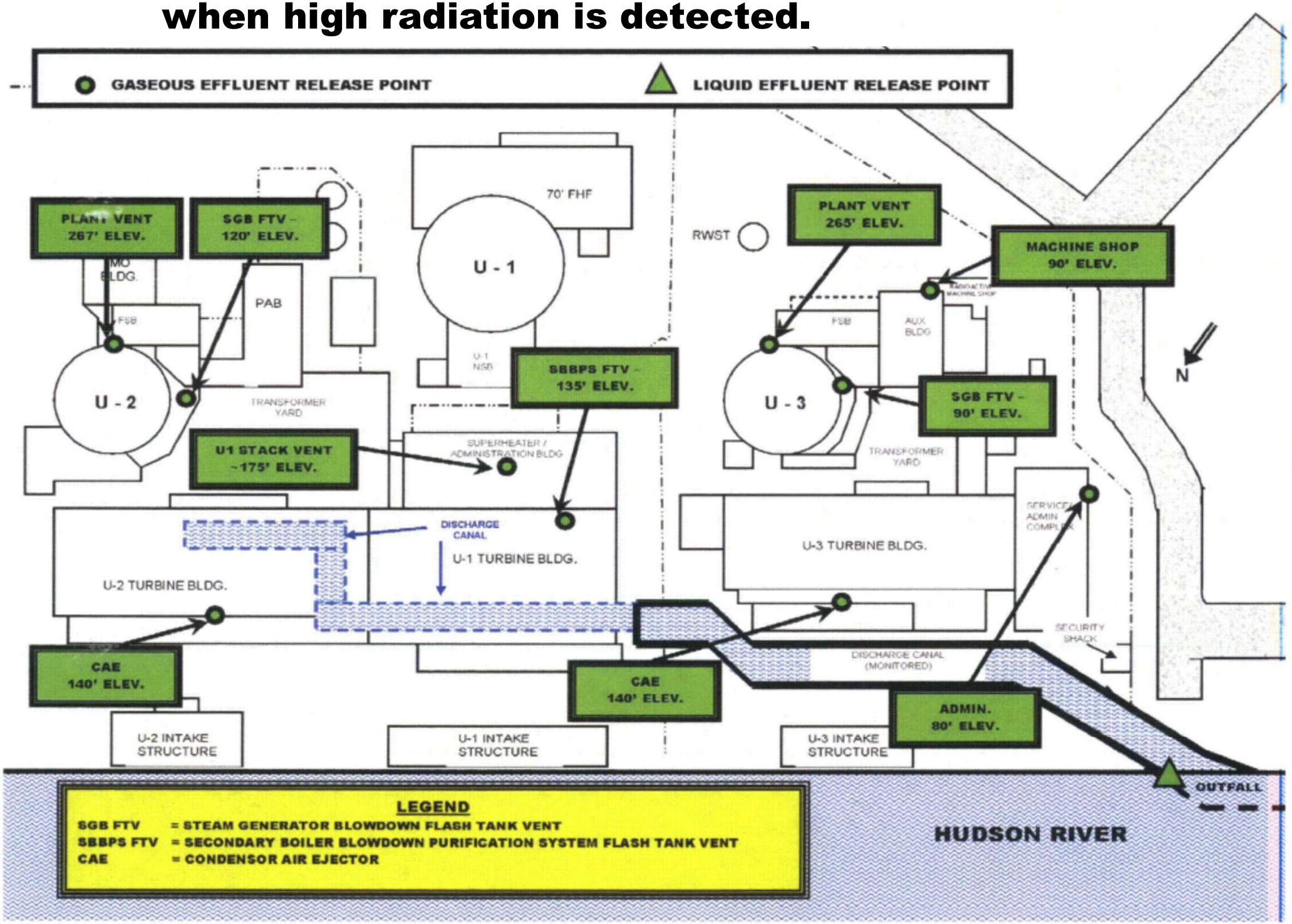
Numerous monitoring wells (MW) check for leaks and spills of contaminated liquid into the soil.

Control of Radioactive Gases



Radioactive gases can be released to the atmosphere by several paths.

Each pathway is monitored and closed when high radiation is detected.



Radioactive Material Accounting

Similar to the liquid release accounting, the contents of buildings are periodically sampled and analyzed to determine the concentrations of radionuclides present. The exhaust flow rates are recorded to then determine how much of each radionuclide was discharged to the air.

Entergy

Facility: Indian Point Energy Center	Page 1 of 65
	YEAR: 2019
Indian Point Units 1, 2 and 3	
Docket Nos.: 50-3, 50-247, & 50-286	
Entergy Nuclear Operations, Inc. (Entergy)	
Annual Radioactive Effluent Release Report	

2.0 Batch Releases:

1. Airborne

Table 2.5-1 - Airborne Batch Releases

Unit 1 and 2 Airborne Releases		Qtr 1	Qtr 2	Qtr 3	Qtr 4	2019
Number of Batch Releases		51	52	51	60	215
Total Time Period	(min)	2800	2750	2470	3300	11320
Maximum Time Period	(min)	85	101	85	173	173
Average Time Period	(min)	54.9	52.8	48.4	55	52.8
Minimum Time Period	(min)	20	3	20	12	3

Unit 3 Airborne Releases		Qtr 1	Qtr 2	Qtr 3	Qtr 4	2019
Number of Batch Releases		27	25	17	14	83
Total Time Period	(min)	2040	2400	2480	1850	8770
Maximum Time Period	(min)	168	193	542	223	542
Average Time Period	(min)	75.5	95.9	146	132	106
Minimum Time Period	(min)	5	4	1	1	1

2. Liquid

Table 2.5-2 – Liquid Batch Releases

Unit 1 and 2 Liquid Releases		Qtr 1	Qtr 2	Qtr 3	Qtr 4	2019
Number of Batch Releases		5	13	2	0	20
Total Time Period	(min)	481	1200	139	0	1820
Maximum Time Period	(min)	114	99	69.5	0	114
Average Time Period	(min)	96.2	92.3	96	0	90
Minimum Time Period	(min)	90	65	43	0	43

Unit 3 Liquid Releases		Qtr 1	Qtr 2	Qtr 3	Qtr 4	2019
Number of Batch Releases		40	29	28	5	102
Total Time Period	(min)	4470	3220	3100	555	11345
Maximum Time Period	(min)	119	124	117	115	124
Average Time Period	(min)	112	111	111	111	111
Minimum Time Period	(min)	107	105	107	108	105

Federal regulations require all liquid and gaseous releases of radioactive materials to be monitored and the totals reported to the NRC annually.

NRC inspectors periodically audit the monitoring and reporting processes.

Source: https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML20136A402

Entergy

Facility: Indian Point Energy Center	Page 1 of 65
	YEAR: 2019
Indian Point Units 1, 2 and 3	
Docket Nos.: 50-3, 50-247, & 50-286	
Entergy Nuclear Operations, Inc. (Entergy)	
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Table 6-1 Summation of Dose Assessments

Year: 2019		Total Body	Max Organ
40 CFR 190 limit ===→	IPEC	25 mrem	75 mrem
Routine Airborne Effluents[1]	Units 1 and 2	1.46E-03	1.46E-03
Routine Liquid Effluents	Units 1 and 2	5.08E-04	7.65E-04
Liquid Releases of C^{14}	Units 1 and 2	1.17E-03	5.83E-03
Airborne Releases of C^{14}	Units 1 and 2	6.51E-02	3.26E-01
Routine Airborne Effluents[1]	Unit 3	3.14E-03	3.14E-03
Routine Liquid Effluents	Unit 3	8.12E-05	2.79E-04
Liquid Releases of C^{14}	Unit 3	1.17E-03	5.83E-03
Airborne Releases of C^{14}	Unit 3	6.18E-02	3.10E-01
Ground Water & Storm Drain Totals	IPEC[2]	5.69E-05	2.30E-04
Direct Shine from areas such as dry cask storage, radwaste storage, SG Mausoleum, etc.	IPEC[3]	3.00E-01	3.00E-01
Indian Point Energy Center Total Dose, per 40 CFR 190	IPEC	4.34E-01	9.54E-01

Note 1: Routine airborne dose in this table is conservatively represented as a sum of Iodine, Particulate, and Tritium dose (excluding C-14, in mrem) with a mrem term added from noble gas gamma air energy (mrad, expressed as mrem). This 'addition' does not represent a real dose and is listed here solely to help demonstrate compliance with 40CFR190. (Doses by type of release and comparison to the specific limits of 10CFR50 Appendix I are summarized on the following pages.)

Note 2: Groundwater curie and dose calculations are provided in Attachment 2.

Note 3: 40CFR190 requires the reporting of total dose, including that of direct shine. Direct shine dose from sources other than dry cask are indistinguishable from background. Direct shine dose is determined from TLDs near the dry cask area and site boundary, compared with REMP TLDs and historical values, and corrected with occupancy factors to determine a bounding, worst case assessment of direct shine dose to a real individual. Details of each year's dose evaluation are available on site.

Federal regulations further require assessment of the radiation dose to the public from the released radioactive materials.

Federal limit on radiation dose to the public is 25 millirem to the body and 75 millirem to the maximum organ.

In 2019, radiation doses to the public from all releases to the air and water of 0.434 millirem to the body and 0.954 millirem to the maximum organ were well below the federal limits

Source: https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML20136A402

The annual reports also provide results from the analyses of samples from the monitoring wells.

Indian Point Units 1, 2 & 3	YEAR: 2019	Page 53 of 65
Annual Radioactive Effluent Release Report		

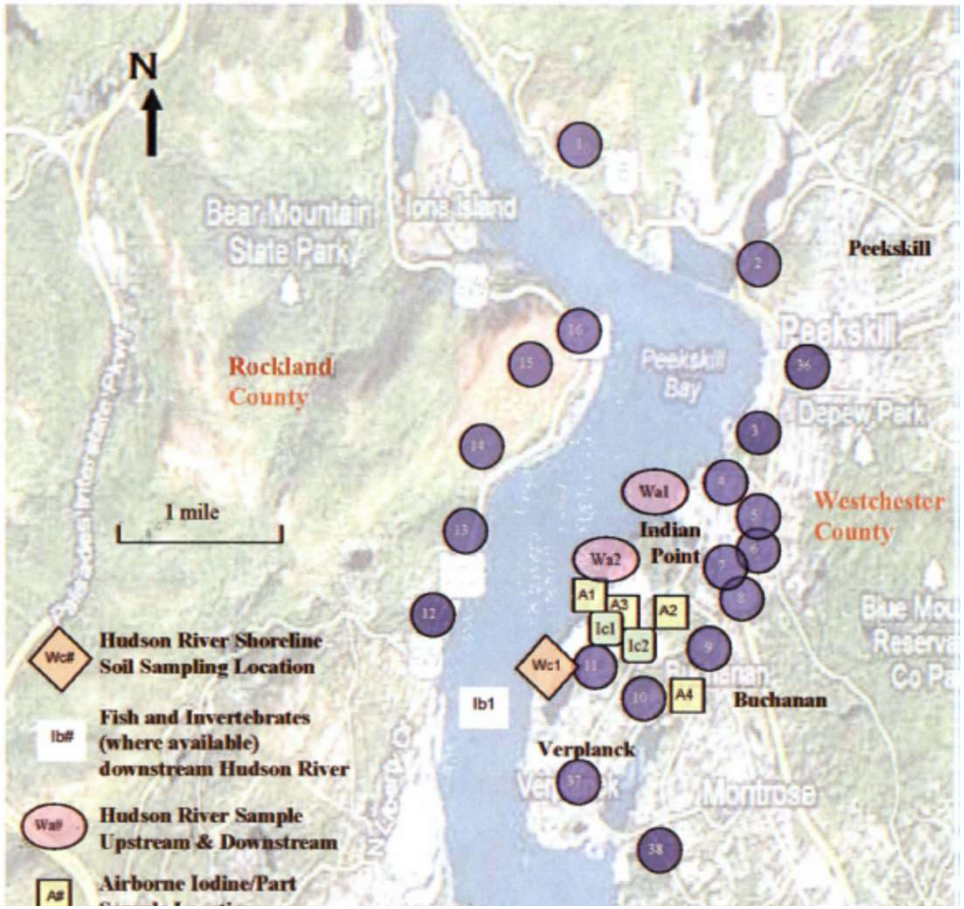
Well ID	Sample Date	2019 Laboratory Analytical Results											
		H-3 Result (pCi/L)	H-3 3 Sigma (Std. Dev.)	Sr-90 Result (pCi/L)	Sr-90 3 Sigma (Std. Dev.)	Cs-137 Result (pCi/L)	Cs-137 3 Sigma (Std. Dev.)	Co-60 Result (pCi/L)	Co-60 3 Sigma (Std. Dev.)	Ni-63 Result (pCi/L)	Ni-63 3 Sigma (Std. Dev.)	Sb-125 Result (pCi/L)	Sb-125 3 Sigma (Std. Dev.)
MW-31-49	3/7/2019	1.67E+02	4.23E+02	0.1	0.8	-3.2	6.0	-3.4	5.2			-5.3	13.1
MW-31-49	5/16/2019	9.84E+01	3.90E+02	0.5	1.3	2.4	7.0	1.8	9.5			6.0	15.6
MW-31-49	8/2/2019	**1.46E+04**	1.12E+03	-0.2	1.2	2.9	5.8	0.6	5.8			3.9	19.1
MW-31-49	10/21/2019	**1.42E+04**	9.81E+02	0.1	0.9	-6.4	7.7	-3.1	6.9			11.6	16.8
MW-31-49	11/5/2019	**4.18E+02**	3.60E+02	0.1	1.4	-5.5	7.0	1.1	8.0			18.4	26.5
MW-31-63	1/16/2019	**1.36E+04**	9.54E+02	-0.9	1.2	0.3	5.0	-0.9	4.1			**43.2**	20.7
MW-31-63	2/11/2019	**2.84E+04**	1.33E+03	0.0	1.3	-2.2	4.4	0.1	4.6			**37.1**	33.3
MW-31-63	3/7/2019	**2.04E+04**	1.33E+03	0.2	1.1	0.1	5.4	2.4	4.7			**44.8**	31.8
MW-31-63	4/18/2019	**2.51E+04**	1.38E+03	-0.4	0.9	1.6	5.3	0.3	4.6			0.0	22.2
MW-31-63	5/16/2019	**1.41E+04**	9.90E+02	-0.6	0.9	-2.0	6.4	1.4	5.9			0.0	38.1
MW-31-63	6/18/2019	**2.68E+04**	1.45E+03	1.6	1.8	0.0	4.7	-0.8	6.0			**33.9**	19.3
MW-31-63	7/9/2019	**3.23E+04**	1.58E+03	0.9	1.7	**10.8**	8.3	1.3	5.0			**32.3**	29.1
MW-31-63	8/2/2019	**3.74E+04**	1.70E+03	-0.4	1.1	0.0	13.1	2.0	5.1			**34.3**	24.4
MW-31-63	9/4/2019	**3.92E+04**	1.71E+03	1.1	1.8	-0.4	6.5	0.2	6.9			33.4	40.5
MW-31-63	10/21/2019	**3.70E+04**	1.51E+03	-0.6	0.9	0.1	5.4	2.2	4.3			**33.8**	27.7
MW-31-63	11/5/2019	**4.14E+04**	1.85E+03	0.1	1.6	1.9	6.7	3.7	6.7			20.0	21.7
MW-31-63	12/5/2019	**4.33E+04**	1.92E+03	0.5	1.6	0.0	5.8	1.1	4.9			28.9	29.7
MW-31-85	3/7/2019	**1.20E+03**	5.13E+02	-0.4	1.0	1.4	4.7	5.0	5.2			4.6	12.5

Source: https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML20136A402

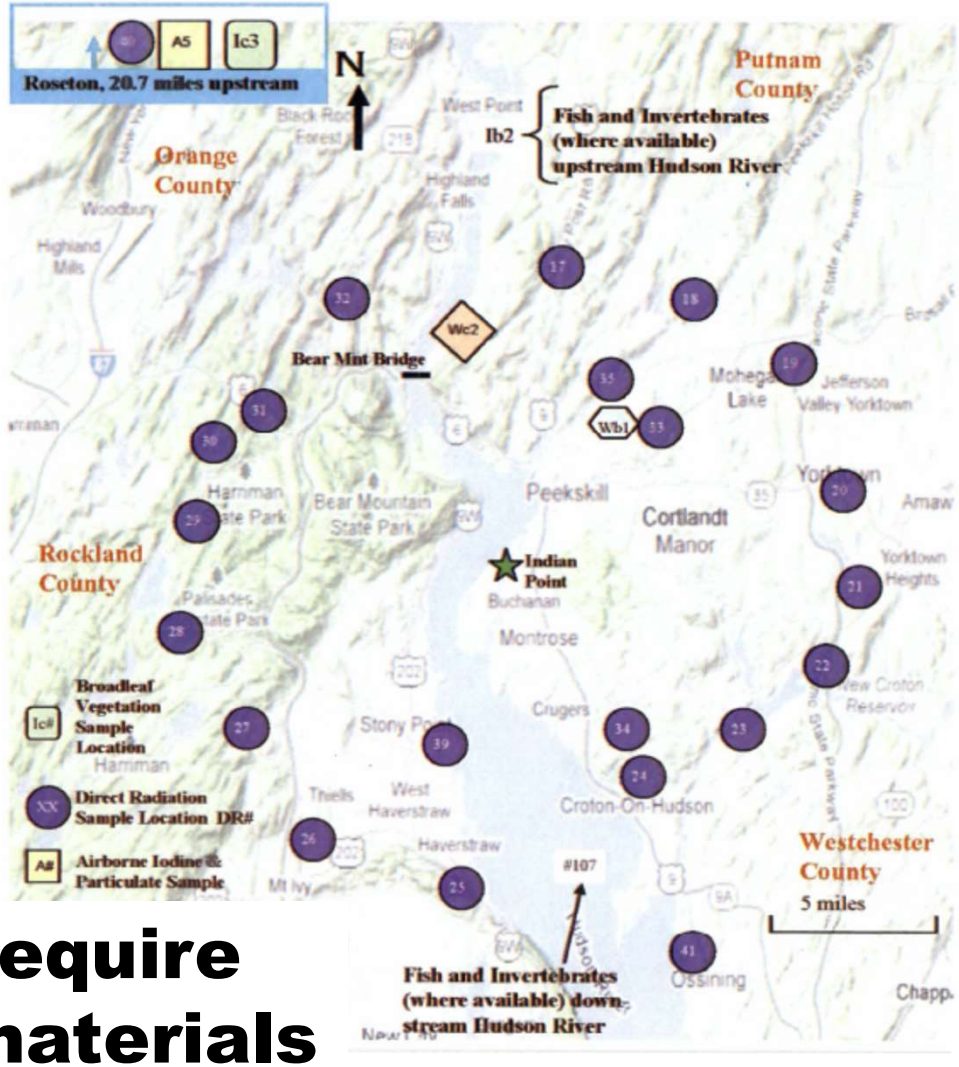
Entergy

Plant: Indian Point Energy Center	Page 1 of 126
	YEAR: 2019
Docket Number: 50-003 (IP1), 50-247 (IP2), 50-286 (IP3)	
Annual Radiological Environmental Operating Report	

SAMPLING LOCATIONS
Within Two Miles of Indian Point



SAMPLING LOCATIONS
Greater than Two Miles from Indian Point



Federal regulations also require monitoring for radioactive materials outside of the plant's outer fences.

Source: https://adamswebsearch2.nrc.gov/webSearch2/main.jsp?AccessionNumber=ML20136A400

Attachment 9.12
Reuter Stokes Locations
Page 1 of 1

Monitor Number	Location	County
1	Roa Hook Road & Cortlandt Town Garage	Westchester
2	Annsville Circle/Intersection of Route 6 and Route 9 Cortlandt	Westchester
3	Hudson Street & Railroad Avenue Peekskill	Westchester
4	Lower South Street. Peekskill	Westchester
5	South Street & Welcher Avenue, Buchanan	Westchester
6	Broadway, Buchanan	Westchester
7	Broadway at Entrance to Service Center, Buchanan	Westchester
8	Broadway across from Unit 3 entrance, Buchanan	Westchester
9	Broadway & St. Patrick's Cemetery, Verplanck	Westchester
10	11th. Street & Highland Avenue, Verplanck	Westchester
11	End of 9th. Street/ West side of Quarry, Verplanck	Westchester
12	Route 9W & Gays Hill Road, Stony Point	Rockland
13	Route 9W & Gays Hill Road North, Stony Point	Rockland
14	Route 9W & Thunder Mountain Road, Stony Point	Rockland
15	Route 9W, Jones Point	Rockland
16	Ayers Road, Jones Point	Rockland

There are 16 radiation monitors located 0.4 to just over 2 miles from the site providing continuous readings to a plant computer that Department of Public Service can access.

Holtec committed to keeping these detectors in service until all spent fuel is in dry storage.

Timing of Radioactive Emissions

The table shows how long it takes 10,000 isotopes of fission products X, Y, and Z to emit radiation.

	Fission Product X	Fission Product Y	Fission Product Z
Fission Product's Half-Life	60 seconds	60 days	60 years
Number Isotopes Originally Present	10,000	10,000	10,000
Radioactive Emissions During First Minute	5,000	0	0
Radioactive Emissions During First Hour	10,000	5	0
Radioactive Emissions During First Day	10,000	115	0
Radioactive Emissions During First Year	10,000	9,852	115
Radioactive Emissions During First Decade	10,000	10,000	1,091

"Half-Life" is the time required, on average, for half of the isotopes of an atom to decay.

	Time After End of Reactor Operation											
Radionuclide	0 days	1 day	1 month	3 months	6 months	1 year	2 years	3 years	4 years	5 years	10 years	100 years
Beryllium 10	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Calcium 41	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%
Niobium 94	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.7%
Carbon 14	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	99.9%	98.8%
Molybdenum 93	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	99.9%	99.9%	99.8%	98.3%
Silver 108m	100.0%	100.0%	100.0%	100.0%	99.9%	99.8%	99.7%	99.5%	99.3%	99.2%	98.4%	84.7%
Nickel 59	100.0%	100.0%	100.0%	99.9%	99.8%	99.7%	99.3%	99.0%	98.7%	98.3%	96.7%	71.5%
Nickel 63	100.0%	100.0%	99.9%	99.8%	99.7%	99.3%	98.6%	97.9%	97.3%	96.6%	93.3%	50.0%
Cesium 137	100.0%	100.0%	99.8%	99.4%	98.9%	97.7%	95.5%	93.3%	91.2%	89.1%	79.4%	9.9%
Strontium 90	100.0%	100.0%	99.8%	99.4%	98.8%	97.6%	95.3%	93.0%	90.8%	88.7%	78.6%	9.0%
Hydrogen 3	100.0%	100.0%	99.5%	98.6%	97.3%	94.5%	89.3%	84.5%	79.8%	75.4%	56.9%	0.4%
Krypton 85	100.0%	100.0%	99.5%	98.4%	96.9%	93.7%	87.9%	82.3%	77.2%	72.3%	52.3%	0.2%
Barium 133	100.0%	100.0%	99.5%	98.4%	96.8%	93.6%	87.7%	82.1%	76.9%	72.0%	51.8%	0.1%
Cobalt 60	100.0%	100.0%	98.9%	96.8%	93.7%	87.7%	76.9%	67.4%	59.1%	51.8%	26.8%	0.0%
Cesium 134	100.0%	99.9%	97.3%	92.2%	85.0%	71.9%	51.7%	37.2%	26.7%	19.2%	3.7%	0.0%
Manganese 54	100.0%	99.8%	93.6%	81.9%	67.0%	44.4%	19.8%	8.8%	3.9%	1.7%	0.0%	0.0%
Cerium 144	100.0%	99.8%	93.0%	80.3%	64.5%	41.1%	16.9%	7.0%	2.9%	1.2%	0.0%	0.0%
Zinc 65	100.0%	99.7%	91.8%	77.4%	60.0%	35.5%	12.6%	4.5%	1.6%	0.6%	0.0%	0.0%
Cobalt 58	100.0%	99.0%	74.6%	41.5%	17.2%	2.8%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Yttrium 91	100.0%	98.8%	69.7%	33.8%	11.4%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Strontium 89	100.0%	98.6%	66.2%	29.1%	8.5%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iron 59	100.0%	98.5%	62.7%	24.6%	6.1%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Barium 140	100.0%	94.7%	19.7%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 131	100.0%	91.7%	7.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 133	100.0%	87.6%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 132	100.0%	80.6%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Tellurium 132	100.0%	80.6%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Molybdenum 99	100.0%	77.7%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Yttrium 90	100.0%	77.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Lanthanum 140	100.0%	66.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 133	100.0%	44.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Strontium-91	100.0%	17.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 135	100.0%	8.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Technetium 99	100.0%	6.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Krypton 88	100.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Manganese 56	100.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Argon 41	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Krypton 87	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 134	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Tellurium 134	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bromine 84	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 135	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rubidium 88	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Praseodymium 144	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rubidium 89	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 138	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

	Last Reactor Operation	Years Since Shutdown as of	08/17/21
Indian Point Unit 1	10/31/74	46.8	
Indian Point Unit 2	04/30/20	1.3	15.6 months
Indian Point Unit 3	04/30/21	0.3	3.6 months

The rows of this table shows radionuclides and their inventories (amounts) as a function of time since reactor operation ended.

These amounts only reflect the contents of the nuclear fuel in the last core operated in the reactor.

Spent fuel removed from the reactor during refueling outages prior to the last cycle of operation would increase these amounts.

But this table illustrates how the passage of time lessens the inventory of radioactive materials.

	Time After End of Reactor Operation											
Radionuclide	0 days	1 day	1 month	3 months	6 months	1 year	2 years	3 years	4 years	5 years	10 years	100 years
Beryllium 10	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Calcium 41	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%
Niobium 94	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.7%
Carbon 14	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	99.9%	98.8%
Molybdenum 93	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	99.9%	99.9%	99.8%	98.3%
Silver 108m	100.0%	100.0%	100.0%	100.0%	99.9%	99.8%	99.7%	99.5%	99.3%	99.2%	98.4%	84.7%
Nickel 59	100.0%	100.0%	100.0%	99.9%	99.8%	99.7%	99.3%	99.0%	98.7%	98.3%	96.7%	71.5%
Nickel 63	100.0%	100.0%	99.9%	99.8%	99.7%	99.3%	98.6%	97.9%	97.3%	96.6%	93.3%	50.0%
Cesium 137	100.0%	100.0%	99.8%	99.4%	98.9%	97.7%	95.5%	93.3%	91.2%	89.1%	79.4%	9.9%
Strontium 90	100.0%	100.0%	99.8%	99.4%	98.8%	97.6%	95.3%	93.0%	90.8%	88.7%	78.6%	9.0%
Hydrogen 3	100.0%	100.0%	99.5%	98.6%	97.3%	94.5%	89.3%	84.5%	79.8%	75.4%	56.9%	0.4%
Krypton 85	100.0%	100.0%	99.5%	98.4%	96.9%	93.7%	87.9%	82.3%	77.2%	72.3%	52.3%	0.2%
Barium 133	100.0%	100.0%	99.5%	98.4%	96.8%	93.6%	87.7%	82.1%	76.9%	72.0%	51.8%	0.1%
Cobalt 60	100.0%	100.0%	98.9%	96.8%	93.7%	87.7%	76.9%	67.4%	59.1%	51.8%	26.8%	0.0%
Cesium 134	100.0%	99.9%	97.3%	92.2%	85.0%	71.9%	51.7%	37.2%	26.7%	19.2%	3.7%	0.0%
Manganese 54	100.0%	99.8%	93.6%	81.9%	67.0%	44.4%	19.8%	8.8%	3.9%	1.7%	0.0%	0.0%
Cerium 144	100.0%	99.8%	93.0%	80.3%	64.5%	41.1%	16.9%	7.0%	2.9%	1.2%	0.0%	0.0%
Zinc 65	100.0%	99.7%	91.8%	77.4%	60.0%	35.5%	12.6%	4.5%	1.6%	0.6%	0.0%	0.0%
Cobalt 58	100.0%	99.0%	74.6%	41.5%	17.2%	2.8%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Yttrium 91	100.0%	98.8%	69.7%	33.8%	11.4%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Strontium 89	100.0%	98.6%	66.2%	29.1%	8.5%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iron 59	100.0%	98.5%	62.7%	24.6%	6.1%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Barium 140	100.0%	94.7%	19.7%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 131	100.0%	91.7%	7.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 133	100.0%	87.6%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 132	100.0%	80.6%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Tellurium 132	100.0%	80.6%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Molybdenum 99	100.0%	77.7%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Yttrium 90	100.0%	77.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Lanthanum 140	100.0%	66.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 133	100.0%	44.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Strontium-91	100.0%	17.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 135	100.0%	8.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Technetium 99	100.0%	6.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Krypton 88	100.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Manganese 56	100.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Argon 41	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Krypton 87	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 134	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Tellurium 134	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bromine 84	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 135	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rubidium 88	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Praseodymium 144	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rubidium 89	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 138	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

	Last Reactor Operation	Years Since Shutdown as of	08/17/21
Indian Point Unit 1	10/31/74	46.8	
Indian Point Unit 2	04/30/20	1.3	15.6 months
Indian Point Unit 3	04/30/21	0.3	3.6 months

The half-life of a radionuclide determines how fast it decays after reactor operation.

For example, Cesium-134 has a half-life of just over 767 days or about two years.

As shown, two years after reactor operation ends, nearly half of the Cesium-134 inventory has decayed away.

Radioactive decay in the form of alpha and beta particles and gamma rays represent radioactive bullets that can harm living things they strike.

Radionuclide	Time After End of Reactor Operation											
	0 days	1 day	1 month	3 months	6 months	1 year	2 years	3 years	4 years	5 years	10 years	100 years
Beryllium 10	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Calcium 41	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%
Niobium 94	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.7%
Carbon 14	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	99.9%	98.8%
Molybdenum 93	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	99.9%	99.9%	99.8%	98.3%
Silver 108m	100.0%	100.0%	100.0%	100.0%	99.9%	99.8%	99.7%	99.5%	99.3%	99.2%	98.4%	84.7%
Nickel 59	100.0%	100.0%	100.0%	99.9%	99.8%	99.7%	99.3%	99.0%	98.7%	98.3%	96.7%	71.5%
Nickel 63	100.0%	100.0%	99.9%	99.8%	99.7%	99.3%	98.6%	97.9%	97.3%	96.6%	93.3%	50.0%
Cesium 137	100.0%	100.0%	99.8%	99.4%	98.9%	97.7%	95.5%	93.3%	91.2%	89.1%	79.4%	9.9%
Strontium 90	100.0%	100.0%	99.8%	99.4%	98.8%	97.6%	95.3%	93.0%	90.8%	88.7%	78.6%	9.0%
Hydrogen 3	100.0%	100.0%	99.5%	98.6%	97.3%	94.5%	89.3%	84.5%	79.8%	75.4%	56.9%	0.4%
Krypton 85	100.0%	100.0%	99.5%	98.4%	96.9%	93.7%	87.9%	82.3%	77.2%	72.3%	52.3%	0.2%
Barium 133	100.0%	100.0%	99.5%	98.4%	96.8%	93.6%	87.7%	82.1%	76.9%	72.0%	51.8%	0.1%
Cobalt 60	100.0%	100.0%	98.9%	96.8%	93.7%	87.7%	76.9%	67.4%	59.1%	51.8%	26.8%	0.0%
Cesium 134	100.0%	99.9%	97.3%	92.2%	85.0%	71.9%	51.7%	37.2%	26.7%	19.2%	3.7%	0.0%
Manganese 54	100.0%	99.8%	93.6%	81.9%	67.0%	44.4%	19.8%	8.8%	3.9%	1.7%	0.0%	0.0%
Cerium 144	100.0%	99.8%	93.0%	80.3%	64.5%	41.1%	16.9%	7.0%	2.9%	1.2%	0.0%	0.0%
Zinc 65	100.0%	99.7%	91.8%	77.4%	60.0%	35.5%	12.6%	4.5%	1.6%	0.6%	0.0%	0.0%
Cobalt 58	100.0%	99.0%	74.6%	41.5%	17.2%	2.8%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Yttrium 91	100.0%	98.8%	69.7%	33.8%	11.4%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Strontium 89	100.0%	98.6%	66.2%	29.1%	8.5%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iron 59	100.0%	98.5%	62.7%	24.6%	6.1%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Barium 140	100.0%	94.7%	19.7%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 131	100.0%	91.7%	7.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 133	100.0%	87.6%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 132	100.0%	80.6%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Tellurium 132	100.0%	80.6%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Molybdenum 99	100.0%	77.7%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Yttrium 90	100.0%	77.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Lanthanum 140	100.0%	66.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 133	100.0%	44.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Strontium-91	100.0%	17.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 135	100.0%	8.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Technetium 99	100.0%	6.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Krypton 88	100.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Manganese 56	100.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Argon 41	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Krypton 87	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 134	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Tellurium 134	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bromine 84	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 135	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rubidium 88	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Praseodymium 144	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rubidium 89	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 138	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

	Last Reactor Operation	Years Since Shutdown as of	08/17/21
Indian Point Unit 1	10/31/74	46.8	
Indian Point Unit 2	04/30/20	1.3	15.6 months
Indian Point Unit 3	04/30/21	0.3	3.6 months

Radionuclides with longer half-lives, such as those shaded in green, are essentially revolvers filled with radioactive bullets not yet fired.

For context, Beryllium-10, Calcium-41 and Niobium-94 could not have caused any harm during the five years since end of reactor operation because they have not yet fired many of their radioactive harm.

Because their revolvers remain loaded, they remain hazards in the future.

	Time After End of Reactor Operation											
Radionuclide	0 days	1 day	1 month	3 months	6 months	1 year	2 years	3 years	4 years	5 years	10 years	100 years
Beryllium 10	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Calcium 41	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%
Niobium 94	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.7%
Carbon 14	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	99.9%	98.8%
Molybdenum 93	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	99.9%	99.9%	99.8%	98.3%
Silver 108m	100.0%	100.0%	100.0%	100.0%	99.9%	99.8%	99.7%	99.5%	99.3%	99.2%	98.4%	84.7%
Nickel 59	100.0%	100.0%	100.0%	99.9%	99.8%	99.7%	99.3%	99.0%	98.7%	98.3%	96.7%	71.5%
Nickel 63	100.0%	100.0%	99.9%	99.8%	99.7%	99.3%	98.6%	97.9%	97.3%	96.6%	93.3%	50.0%
Cesium 137	100.0%	100.0%	99.8%	99.4%	98.9%	97.7%	95.5%	93.3%	91.2%	89.1%	79.4%	9.9%
Strontium 90	100.0%	100.0%	99.8%	99.4%	98.8%	97.6%	95.3%	93.0%	90.8%	88.7%	78.6%	9.0%
Hydrogen 3	100.0%	100.0%	99.5%	98.6%	97.3%	94.5%	89.3%	84.5%	79.8%	75.4%	56.9%	0.4%
Krypton 85	100.0%	100.0%	99.5%	98.4%	96.9%	93.7%	87.9%	82.3%	77.2%	72.3%	52.3%	0.2%
Barium 133	100.0%	100.0%	99.5%	98.4%	96.8%	93.6%	87.7%	82.1%	76.9%	72.0%	51.8%	0.1%
Cobalt 60	100.0%	100.0%	98.9%	96.8%	93.7%	87.7%	76.9%	67.4%	59.1%	51.8%	26.8%	0.0%
Cesium 134	100.0%	99.9%	97.3%	92.2%	85.0%	71.9%	51.7%	37.2%	26.7%	19.2%	3.7%	0.0%
Manganese 54	100.0%	99.8%	93.6%	81.9%	67.0%	44.4%	19.8%	8.8%	3.9%	1.7%	0.0%	0.0%
Cerium 144	100.0%	99.8%	93.0%	80.3%	64.5%	41.1%	16.9%	7.0%	2.9%	1.2%	0.0%	0.0%
Zinc 65	100.0%	99.7%	91.8%	77.4%	60.0%	35.5%	12.6%	4.5%	1.6%	0.6%	0.0%	0.0%
Cobalt 58	100.0%	99.0%	74.6%	41.5%	17.2%	2.8%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Yttrium 91	100.0%	98.8%	69.7%	33.8%	11.4%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Strontium 89	100.0%	98.6%	66.2%	29.1%	8.5%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iron 59	100.0%	98.5%	62.7%	24.6%	6.1%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Barium 140	100.0%	94.7%	19.7%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 131	100.0%	91.7%	7.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 133	100.0%	87.6%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 132	100.0%	80.6%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Tellurium 132	100.0%	80.6%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Molybdenum 99	100.0%	77.7%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Yttrium 90	100.0%	77.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Lanthanum 140	100.0%	66.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 133	100.0%	44.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Strontium-91	100.0%	17.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 135	100.0%	8.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Technetium 99	100.0%	6.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Krypton 88	100.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Manganese 56	100.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Argon 41	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Krypton 87	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 134	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Tellurium 134	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bromine 84	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 135	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rubidium 88	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Praseodymium 144	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rubidium 89	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 138	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

	Last Reactor Operation	Years Since Shutdown as of	08/17/21
Indian Point Unit 1	10/31/74	46.8	
Indian Point Unit 2	04/30/20	1.3	15.6 months
Indian Point Unit 3	04/30/21	0.3	3.6 months

Radionuclides with short half-lives, such as those shaded in green, are essentially empty revolvers whose radioactive bullets have already fired.

Thus, three months after the end of reactor operation, Iodine-131 and radionuclides listed below it in the table no longer pose a future radioactive threat because their radioactive bullets have been fired.

	Time After End of Reactor Operation											
Radionuclide	0 days	1 day	1 month	3 months	6 months	1 year	2 years	3 years	4 years	5 years	10 years	100 years
Beryllium 10	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Calcium 41	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%
Niobium 94	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.7%
Carbon 14	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	99.9%	98.8%
Molybdenum 93	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	99.9%	99.9%	99.8%	98.3%
Silver 108m	100.0%	100.0%	100.0%	100.0%	99.9%	99.8%	99.7%	99.5%	99.3%	99.2%	98.4%	84.7%
Nickel 59	100.0%	100.0%	100.0%	99.9%	99.8%	99.7%	99.3%	99.0%	98.7%	98.3%	96.7%	71.5%
Nickel 63	100.0%	100.0%	99.9%	99.8%	99.7%	99.3%	98.6%	97.9%	97.3%	96.6%	93.3%	50.0%
Cesium 137	100.0%	100.0%	99.8%	99.4%	98.9%	97.7%	95.5%	93.3%	91.2%	89.1%	79.4%	9.9%
Strontium 90	100.0%	100.0%	99.8%	99.4%	98.8%	97.6%	95.3%	93.0%	90.8%	88.7%	78.6%	9.0%
Hydrogen 3	100.0%	100.0%	99.5%	98.6%	97.3%	94.5%	89.3%	84.5%	79.8%	75.4%	56.9%	0.4%
Krypton 85	100.0%	100.0%	99.5%	98.4%	96.9%	93.7%	87.9%	82.3%	77.2%	72.3%	52.3%	0.2%
Barium 133	100.0%	100.0%	99.5%	98.4%	96.8%	93.6%	87.7%	82.1%	76.9%	72.0%	51.8%	0.1%
Cobalt 60	100.0%	100.0%	98.9%	96.8%	93.7%	87.7%	76.9%	67.4%	59.1%	51.8%	26.8%	0.0%
Cesium 134	100.0%	99.9%	97.3%	92.2%	85.0%	71.9%	51.7%	37.2%	26.7%	19.2%	3.7%	0.0%
Manganese 54	100.0%	99.8%	93.6%	81.9%	67.0%	44.4%	19.8%	8.8%	3.9%	1.7%	0.0%	0.0%
Cerium 144	100.0%	99.8%	93.0%	80.3%	64.5%	41.1%	16.9%	7.0%	2.9%	1.2%	0.0%	0.0%
Zinc 65	100.0%	99.7%	91.8%	77.4%	60.0%	35.5%	12.6%	4.5%	1.6%	0.6%	0.0%	0.0%
Cobalt 58	100.0%	99.0%	74.6%	41.5%	17.2%	2.8%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Yttrium 91	100.0%	98.8%	69.7%	33.8%	11.4%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Strontium 89	100.0%	98.6%	66.2%	29.1%	8.5%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iron 59	100.0%	98.5%	62.7%	24.6%	6.1%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Barium 140	100.0%	94.7%	19.7%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 131	100.0%	91.7%	7.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 133	100.0%	87.6%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 132	100.0%	80.6%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Tellurium 132	100.0%	80.6%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Molybdenum 99	100.0%	77.7%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Yttrium 90	100.0%	77.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Lanthanum 140	100.0%	66.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 133	100.0%	44.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Strontium-91	100.0%	17.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 135	100.0%	8.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Technetium 99	100.0%	6.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Krypton 88	100.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Manganese 56	100.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Argon 41	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Krypton 87	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 134	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Tellurium 134	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bromine 84	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 135	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rubidium 88	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Praseodymium 144	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rubidium 89	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 138	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

	Last Reactor Operation	Years Since Shutdown as of	08/17/21
Indian Point Unit 1	10/31/74	46.8	
Indian Point Unit 2	04/30/20	1.3	15.6 months
Indian Point Unit 3	04/30/21	0.3	3.6 months

Indian Point Unit 1 ended its reactor operation in October 1974.

Manganese-54 and the radionuclides listed below it in the table are now empty revolvers without radioactive bullets remaining to fire.

Radionuclide	Time After End of Reactor Operation											
	0 days	1 day	1 month	3 months	6 months	1 year	2 years	3 years	4 years	5 years	10 years	100 years
Beryllium 10	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Calcium 41	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%
Niobium 94	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.7%
Carbon 14	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	99.9%	98.8%
Molybdenum 93	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	99.9%	99.9%	99.8%	98.3%
Silver 108m	100.0%	100.0%	100.0%	100.0%	99.9%	99.8%	99.7%	99.5%	99.3%	99.2%	98.4%	84.7%
Nickel 59	100.0%	100.0%	100.0%	99.9%	99.8%	99.7%	99.3%	99.0%	98.7%	98.3%	96.7%	71.5%
Nickel 63	100.0%	100.0%	99.9%	99.8%	99.7%	99.3%	98.6%	97.9%	97.3%	96.6%	93.3%	50.0%
Cesium 137	100.0%	100.0%	99.8%	99.4%	98.9%	97.7%	95.5%	93.3%	91.2%	89.1%	79.4%	9.9%
Strontium 90	100.0%	100.0%	99.8%	99.4%	98.8%	97.6%	95.3%	93.0%	90.8%	88.7%	78.6%	9.0%
Hydrogen 3	100.0%	100.0%	99.5%	98.6%	97.3%	94.5%	89.3%	84.5%	79.8%	75.4%	56.9%	0.4%
Krypton 85	100.0%	100.0%	99.5%	98.4%	96.9%	93.7%	87.9%	82.3%	77.2%	72.3%	52.3%	0.2%
Barium 133	100.0%	100.0%	99.5%	98.4%	96.8%	93.6%	87.7%	82.1%	76.9%	72.0%	51.8%	0.1%
Cobalt 60	100.0%	100.0%	98.9%	96.8%	93.7%	87.7%	76.9%	67.4%	59.1%	51.8%	26.8%	0.0%
Cesium 134	100.0%	99.9%	97.3%	92.2%	85.0%	71.9%	51.7%	37.2%	26.7%	19.2%	3.7%	0.0%
Manganese 54	100.0%	99.8%	93.6%	81.9%	67.0%	44.4%	19.8%	8.8%	3.9%	1.7%	0.0%	0.0%
Cerium 144	100.0%	99.8%	93.0%	80.3%	64.5%	41.1%	16.9%	7.0%	2.9%	1.2%	0.0%	0.0%
Zinc 65	100.0%	99.7%	91.8%	77.4%	60.0%	35.5%	12.6%	4.5%	1.6%	0.6%	0.0%	0.0%
Cobalt 58	100.0%	99.0%	74.6%	41.5%	17.2%	2.8%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Yttrium 91	100.0%	98.8%	69.7%	33.8%	11.4%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Strontium 89	100.0%	98.6%	66.2%	29.1%	8.5%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iron 59	100.0%	98.5%	62.7%	24.6%	6.1%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Barium 140	100.0%	94.7%	19.7%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 131	100.0%	91.7%	7.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 133	100.0%	87.6%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 132	100.0%	80.6%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Tellurium 132	100.0%	80.6%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Molybdenum 99	100.0%	77.7%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Yttrium 90	100.0%	77.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Lanthanum 140	100.0%	66.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 133	100.0%	44.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Strontium-91	100.0%	17.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 135	100.0%	8.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Technetium 99	100.0%	6.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Krypton 88	100.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Manganese 56	100.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Argon 41	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Krypton 87	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 134	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Tellurium 134	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bromine 84	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 135	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rubidium 88	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Praseodymium 144	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rubidium 89	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 138	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

	Last Reactor Operation	Years Since Shutdown as of	08/17/21
Indian Point Unit 1	10/31/74	46.8	
Indian Point Unit 2	04/30/20	1.3	15.6 months
Indian Point Unit 3	04/30/21	0.3	3.6 months

Indian Point Unit 2 ended its reactor operation on April 30 2020. Barium-140 and the radionuclides listed below it in the table are now empty revolvers without radioactive bullets remaining to fire.

Radionuclide	Time After End of Reactor Operation											
	0 days	1 day	1 month	3 months	6 months	1 year	2 years	3 years	4 years	5 years	10 years	100 years
Beryllium 10	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Calcium 41	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%
Niobium 94	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.7%
Carbon 14	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	99.9%	98.8%
Molybdenum 93	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	99.9%	99.9%	99.8%	98.3%
Silver 108m	100.0%	100.0%	100.0%	100.0%	99.9%	99.8%	99.7%	99.5%	99.3%	99.2%	98.4%	84.7%
Nickel 59	100.0%	100.0%	100.0%	99.9%	99.8%	99.7%	99.3%	99.0%	98.7%	98.3%	96.7%	71.5%
Nickel 63	100.0%	100.0%	99.9%	99.8%	99.7%	99.3%	98.6%	97.9%	97.3%	96.6%	93.3%	50.0%
Cesium 137	100.0%	100.0%	99.8%	99.4%	98.9%	97.7%	95.5%	93.3%	91.2%	89.1%	79.4%	9.9%
Strontium 90	100.0%	100.0%	99.8%	99.4%	98.8%	97.6%	95.3%	93.0%	90.8%	88.7%	78.6%	9.0%
Hydrogen 3	100.0%	100.0%	99.5%	98.6%	97.3%	94.5%	89.3%	84.5%	79.8%	75.4%	56.9%	0.4%
Krypton 85	100.0%	100.0%	99.5%	98.4%	96.9%	93.7%	87.9%	82.3%	77.2%	72.3%	52.3%	0.2%
Barium 133	100.0%	100.0%	99.5%	98.4%	96.8%	93.6%	87.7%	82.1%	76.9%	72.0%	51.8%	0.1%
Cobalt 60	100.0%	100.0%	98.9%	96.8%	93.7%	87.7%	76.9%	67.4%	59.1%	51.8%	26.8%	0.0%
Cesium 134	100.0%	99.9%	97.3%	92.2%	85.0%	71.9%	51.7%	37.2%	26.7%	19.2%	3.7%	0.0%
Manganese 54	100.0%	99.8%	93.6%	81.9%	67.0%	44.4%	19.8%	8.8%	3.9%	1.7%	0.0%	0.0%
Cerium 144	100.0%	99.8%	93.0%	80.3%	64.5%	41.1%	16.9%	7.0%	2.9%	1.2%	0.0%	0.0%
Zinc 65	100.0%	99.7%	91.8%	77.4%	60.0%	35.5%	12.6%	4.5%	1.6%	0.6%	0.0%	0.0%
Cobalt 58	100.0%	99.0%	74.6%	41.5%	17.2%	2.8%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%
Yttrium 91	100.0%	98.8%	69.7%	33.8%	11.4%	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Strontium 89	100.0%	98.6%	66.2%	29.1%	8.5%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iron 59	100.0%	98.5%	62.7%	24.6%	6.1%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Barium 140	100.0%	94.7%	19.7%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 131	100.0%	91.7%	7.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 133	100.0%	87.6%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 132	100.0%	80.6%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Tellurium 132	100.0%	80.6%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Molybdenum 99	100.0%	77.7%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Yttrium 90	100.0%	77.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Lanthanum 140	100.0%	66.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 133	100.0%	44.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Strontium-91	100.0%	17.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 135	100.0%	8.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Technetium 99	100.0%	6.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Krypton 88	100.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Manganese 56	100.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Argon 41	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Krypton 87	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Iodine 134	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Tellurium 134	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bromine 84	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 135	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rubidium 88	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Praseodymium 144	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Rubidium 89	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Xenon 138	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

	Last Reactor Operation	Years Since Shutdown as of	08/17/21
Indian Point Unit 1	10/31/74	46.8	
Indian Point Unit 2	04/30/20	1.3	15.6 months
Indian Point Unit 3	04/30/21	0.3	3.6 months

Indian Point Unit 3 ended its reactor operation on April 30 2021. Iodine-131 and the radionuclides listed below it in the table are now empty revolvers without radioactive bullets remaining to fire.